International Journal of Modern Communication Technologies & Research (IJMCTR)
ISSN: 2321-0850, Volume-2, Issue-4, April 2014

Design and simulation of compact hairpin band pass filter

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***Abstract*— In this paper we presented analysis and simulation of microwave hairpin filters. A hairpin band pass filter is designed to operate at center frequency of 2.7 GHz with a bandwidth of 506 MHz and return loss of -25dB. This frequency is presenting for GSM, GPS wireless LAN application and operates in the ISM band. To design hairpin filter several steps are considered which includes filter order, low pass prototype, low pass to band pass transformation and finally layout of the filter.**

***Index Terms*—GSM, GPS, LAN**

I. INTRODUCTION

Band pass filters are essential part of any signal processing or communication systems, the integral part of superhetrodyne receivers which are currently employed in many RF/Microwave communication systems. At Microwave Frequencies the discrete components are replaced by transmission lines, for low power applications microstrip are used which provide cheaper and smaller solution of Band Pass Filter. This Paper describes about the design of the microwave Bandpass filter by using microstrip technology. There are many possible techniques used to create microstrip filters A fifth order chebyshev hairpin filter is designed.

II. BASIC THEORY

Out of various bandpass microstrip filters, Hairpin filter is one of the most commonly used. The concept of hairpin filter is same as parallel coupled half wavelength resonator filters. The advantage of hairpin filter over end coupled and parallel coupled microstrip is its low space utilization. In hairpin filter space is saved by folding the resonator which is half wavelength long. Also the hairpin design is simple then the other microwave filters.

(a) (b)

Figure 2.1: (a) tapped line input 5-pole Hairpin Filter

(b) coupled line input Hairpin Filter

Manuscript received April 18, 2014

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The designing equations of hairpin filter are given by

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi}{2}\frac{FBW}{g_0 g_1}} \quad \textbf{(1a)}$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_j g_{j+1}}} \text{ For j=1 to n-1} \quad \textbf{(1b)}$$

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi}{2}\frac{FBW}{g_n g_{n+1}}} \quad \textbf{(1c)}$$

Where g_0, g_1… g_n are the element of a ladder-type low-pass prototype with a Normalized cutoff $\Omega_c = 1$, and *FBW* is the fractional bandwidth of band-pass filter. $J_{j,\ j+1}$ are the characteristic admittances of *J*-inverters and Y_0 is the characteristic admittance of the lines. The equation above will be use in end-coupled line filter because the both types of filter can have the same low-pass network representation.

By using the J-inverters, even and odd-mode impedances of coupled line microstrip line is calculated by

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0}[1 + \frac{J_{j,j+1}}{Y_0} + (\frac{J_{j,j+1}}{Y_0})^2]$$

for j=0 to n **(2a)**

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}[1 - \frac{J_{j,j+1}}{Y_0} + (\frac{J_{j,j+1}}{Y_0})^2]$$

for j=0 to n **(2b)**

III. DESIGN METHODOLOGY

A microstrip hairpin bandpass filter is designed to have a fractional bandwidth 20% or *FBW* = 0.2 at a midband frequency f_0 = 2 GHz .A five pole (*n*=5) Chebyshev lowpass prototype with a passband ripple of 0.1 dB is chosen. The lowpass prototype parameters, given for a normalized lowpass cutoff frequency as in equation 2 are $\Omega_c = 1$, are $g_0 = g_6 = 1.0$, $g_1 = g_5 = 1.1468$, $g_2 = g_4 = 1.3712$, and $g_3 = 1.9750$.

The next step of the filter design is to find the dimensions of coupled microstrip lines that exhibit the desired even- and odd mode impedances. First of all, determine microstrip shape

ratios (w/d) s. Then it can relate coupled line ratios to single line ratios.
For a single microstrip line,

$$Z_{ose} = \frac{(Z_{oe})_{j,j+1}}{2} \qquad \textbf{(3.1)}$$
$$Z_{oso} = \frac{(Z_{oo})_{j,j+1}}{2}$$

Use single line equations to find (w/h)se and (w/h)so from Zose and Zoso. With the given ε_r =4.2, find that for Zo=50, w/h is approximately 1.95. Therefore, $W/h \leq 2$ has been chosen for this case.

$$For \frac{W}{h} \leq 2$$
$$\frac{W}{h} = \frac{8\exp(A)}{\exp(2A)-2} \qquad \textbf{(3.2)}$$

With
$$A = \frac{Z_c}{60}\left\{\frac{\varepsilon_r+1}{2}\right\}^{0.5} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left\{0.23+\frac{0.11}{\varepsilon_r}\right\} \qquad \textbf{(3.4)}$$

At that point, it's able to find (w/h)se and (w/h)so by applying Zose and Zoso (as Zc) to the single line microstrip equations. The point at which it reach w/h and s/h for the desired coupled microstrip line using a family of approximate equations as following

$$\frac{s}{h} = \frac{2}{\pi}\cosh^{-1}\left[\frac{\cosh\left(\left(\frac{\pi}{2}\right)\left(\frac{w}{h}\right)_{se}\right) + \cosh\left(\left(\frac{\pi}{2}\right)\left(\frac{w}{h}\right)_{so}\right) - 2}{\cosh\left(\left(\frac{\pi}{2}\right)\left(\frac{w}{h}\right)_{so}\right) - \cosh\left(\left(\frac{\pi}{2}\right)\left(\frac{w}{h}\right)_{se}\right)}\right]$$

(3.5a)

$$\frac{W}{h} = \frac{1}{\pi}\left[\cosh^{-1}\frac{1}{2}\left(\left(\cosh\left(\frac{\pi S}{2h}\right)-1\right) + \left(\cosh\left(\frac{\pi S}{2h}\right)+1\right)\cosh\left(\left(\frac{\pi}{2}\right)\left(\frac{W}{h}\right)_{se}\right)\right) - \left(\frac{\pi S}{2h}\right)\right]$$

(3.5b)

The microstrip transmission line by an overall dielectric constant in order to assume TEM propagation. There are a number of formulas, listed for the calculation of ε_{eff} . The most basic formula is given by Pozar as follows: [2]

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{\sqrt{1+\frac{12h}{W}}} \qquad \textbf{(3.6)}$$

Once the effective dielectric constant of a microstrip is calculated, the wavelength of the quasi-TEM mode of microstrip is given by

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{re}}} = \frac{300}{f(GHz)\sqrt{\varepsilon_{re}}}mm \qquad \textbf{(3.7)}$$

Thus the required resonator, $\ell = \frac{\lambda_g}{4} = \frac{c}{4f\sqrt{\varepsilon_{re}}}$ **(3.8)**

Using the design equations for coupled microstrip lines given (3.5a) and (3.5b), the width and spacing for each sections are found.

The layout of the proposed filter design with all the determined dimensions is illustrated in Figure 3.1. The size of filter is 12 X 20 mm which is compact then the conventional fiter.

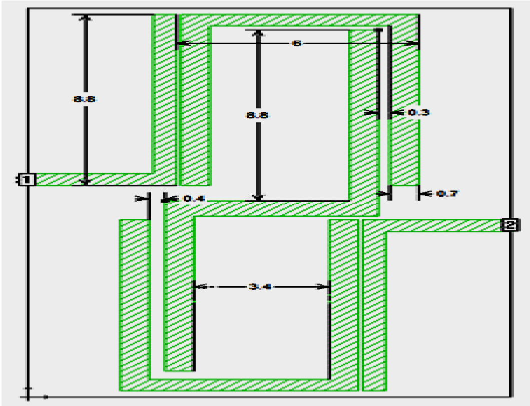

Figure.3.1: Dimensions of proposed compact hairpin bandpass filter

IV. RESULTS AND ANALYSES

The response of proposed filter is in figure 4.1 As shown in figure proposed filter gave a center frequency of 2.75 GHz. Spurious modes which do appear due to in-homogeneities of the microstrip [7, 8] are not shown here.

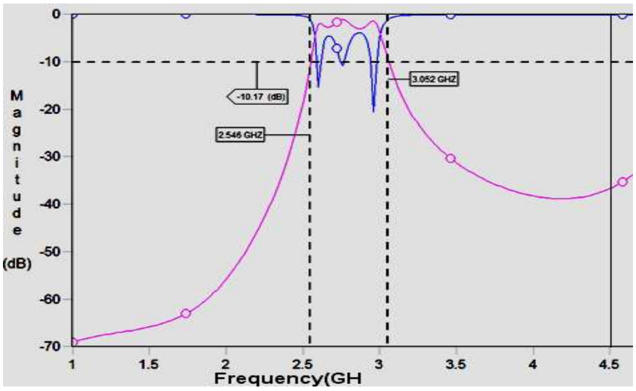

Figure.4.1: S11(blue line) and S12 (pink line) parameters of the proposed hairpin filter

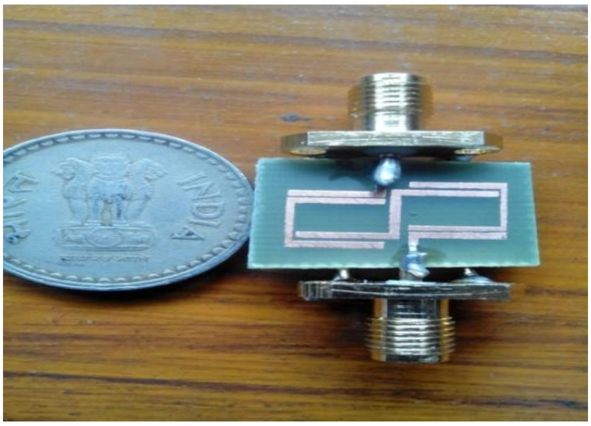

Figure 4.4 Actual size of proposed filter

V. CONCLUSION

The Hairpin filter is simulated. The layout of the final filter design with all the determined dimensions is illustrated. The filter is quite compact with a substrate size of 12 by 20 mm. The input and output resonators are slightly shortened to compensate for the effect of the tapping line and the adjacent coupled resonator. The EM simulated performance of the filter is shown in figure 4.1

VI. FUTURE WORK

Physical development and measurement of RF filters design for more accurate design. Use additional software such as ADS simulations to compare the results with sonnet to accurately determine the final design.

REFERENCES

[1] Matthaei, L. Young, and E. M. T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*. Boston, MA: Artech House, 1980.

[2]D. M. Pozar, "Microwave Engineering", Second Edition, Wiley and Sons, 1998.

[3] R. Rhea, *HF Filter Design and Computer Simulation.* Atlanta, GA: Noble Publishing, 1994.

[4] T. Edwards, *Foundations for Microstrip Circuit Design, 2nd edition*, England: John Wiley & Sons Ltd.,1981.

[5] N. Toledo, "*Practical Techniques for designing Microstrip tapped hairpin resonator filters on FR4 laminates"* 2nd National ECE Conference, Manila, Philippines, November 2001.

[6] Eagleware Corporation, " TLine Program," *Genesys version 8.1*, Norcross, GA, May 2002.

[7] T. Yamaguchi, T. Fujii, T. Kawai, and I. Ohta, "Parallel-coupled microstrip filters with periodic oating conductors on coupled-edges for spurious suppression," IEEE MTT-S International Microwave Symposium Digest, 2008.

[8] K. Singh, "Design and analysis of novel microstrip filter at l-band," in Agilent EESoF 2005 India User Group Meeting, 2005.

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